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EPR study of some rare-earth ions (Dy^{3+}, Tb^{3+}, and Nd^{3+}) in $YBa_2Cu_3O_6$-compound

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Abstract

We investigate the low temperature X-band electron paramagnetic resonance (EPR) of $YBa_2Cu_3O_x$ compounds with $x \cong 6.0$ doped with Dy^{3+}, Tb^{3+}, and Nd^3. The EPR spectra of Dy^{3+} and Tb^{3+} have been identified. The EPR of Tb^{3+} is used also to study the effect of suppression of high T_c superconductivity by doping with Tb^{3+}. The EPR of Nd^{3+} is probably masked by the intense resonance of Cu^{2+}. All experimental EPR results compare well with theoretical estimations.

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Keywords: EPR; ESR; HTSC; $YBa_2Cu_3O_x$; Rare-earth ions

1. Introduction

$YBa_2Cu_3O_x$ (YBaCuO) with $x > 6.35$ is a high T_c superconductor ($T_c \approx 92$ K for $x \approx 7.0$) which has been studied by different techniques including methods of magnetic resonance. Among them until recently nuclear magnetic resonance (NMR) was by far dominant. The application of electron paramagnetic resonance (EPR) to high T_c cuprates was restricted by the problem of EPR silence in these compounds [1]. The EPR line broadening estimated from the spin–phonon interaction ($\cong 10^{10}$ Hz) [2] is too large to detect the spectrum with EPR spectrometers working at the usual frequencies. Strong EPR signals observed at $g \sim 2$–2.2 on the nominally pure high T_c cuprates either at $T < 40$ K [3–5] or at higher temperatures [6,7] were probably due to impurity phases or result from atmospheric degradation [1]. A further approach for EPR studies of high T_c cuprates is to dope these compounds with small amounts of some paramagnetic ions to probe magnetic spin susceptibility and crystal fields of the CuO_2 bilayers. The EPR of rare-earth ions (R^{3+}) such as Gd^{3+} [8–10], Er^{3+}, and Yb^{3+} [11–13] has been used to investigate the intrinsic behavior of YBaCuO. With this technique it is possible to obtain data on the superconducting gap and pseudo-gap similar to those measured by inelastic neutron scattering and NMR. The corresponding g-values of rare-earth ions derived from EPR experiments can be used to determine exactly the parameters of the crystalline electric field (CEF) which are usually extracted from inelastic neutron scattering studies. The knowledge of g-values and corresponding magnetic moments allows to estimate dipole–dipole and exchange interactions both in diluted and concentrated compounds. The advantage of the EPR technique in this context is its time domain of observation being two to three orders of magnitude shorter than that of NMR. In the present work we extend the EPR investigations to some other R^{3+}-ions (Dy^{3+}, Tb^{3+}, Nd^{3+}) in order to clarify their widely discussed real valent states and positions in YBaCuO.

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